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New stratigraphic and geographic occurrences of *Isognomon* (Mollusca: Bivalvia) from the Eocene of California and Oregon

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Abstract. The bivalve *Isognomon* (*Isognomon*) *clarki* (Effinger, 1938), previously only known from the upper Eocene part (Galvinian Stage) of the Lincoln Creek Formation of southwestern Washington, is reported here from five other Eocene formations. Four are in southern California: the upper Juncal Formation, the upper Torrey Sandstone, the basal Tejon Formation, and the Coldwater Sandstone; fifth is the Keasey Formation of northwestern Oregon. Except in the upper Juncal Formation, the presence of *Isognomon* specimens was previously unrecorded. The geologic age range of this species is extended downward into the middle Eocene ("Domengine Stage"). *Isognomon* (*I.*) *clarki* is the only species of its genus known from the Eocene of the West Coast, and this study is the first documentation that this genus formed dense populations in the Eocene. Most of these populations are in coarse-grained pebbly sandstone sediments that indicate nearshore conditions. Rare specimens in the Lincoln Creek and Keasey formations are anomalous because they are in deep-water fine-grained sediments.

Introduction

The bivalve *Isognomon* is rare in the fossil record of the West Coast (California, Oregon, and Washington). Only two species are known, and their occurrence is very localized. This scarcity is probably linked to the high-energy habitat of *Isognomon* species, which commonly inhabited intertidal areas subject to erosion. The earliest West Coast species known is *Isognomon* (*Isognomon*) *clarki* (Effinger, 1938) from the Eocene part of the Lincoln Creek Formation of Washington. In addition, *Isognomon* sp. (Clark and Woodford 1927) from the Meganos Formation and *Isognomon* n. sp.? Givens (1974) from the Juncal Formation have been reported from Eocene rocks of California.

The only West Coast Oligocene species is *Isognomon panzana* (Loel and Corey, 1932) from the upper Oligocene through lower Miocene Vaqueros Formation, California. The cooler conditions that predominated from middle Miocene through Recent times are the inferred cause of the elimination of *Isognomon* from the West Coast's higher latitudes. Today in western North America, there are only two species of *Isognomon*, extending north only as far as Baja California, primarily in warm lagoons (Keen 1971).

Four previously unknown stratigraphic occurrences of West Coast Paleogene *Isognomon* can now be added. These are the upper Torrey Sandstone, San Diego County, southern California; the basal Tejon Formation, Kern County, south-central California; the Coldwater Sandstone, Ventura County, southern California; and the upper Keasey Formation, Columbia County, northwestern Oregon (Figure 1). In all these Eocene formations, except the Meganos Formation, I believe the specimens represent *I.* (*I.*) *clarki* (Effinger). The Meganos Formation occurrence is not included at this time because there is not enough material to allow a conclusive determination.

Methods

During field investigations of the Tejon Formation, I collected abundant specimens of *Isognomon.* The other three previously unknown stratigraphic occurrences are based on museum material I identified while examining collections in museums. The primary type specimens of *I.* (*I.*) *clarki* and the hypotypes from the Juncal Formation were borrowed from museums.

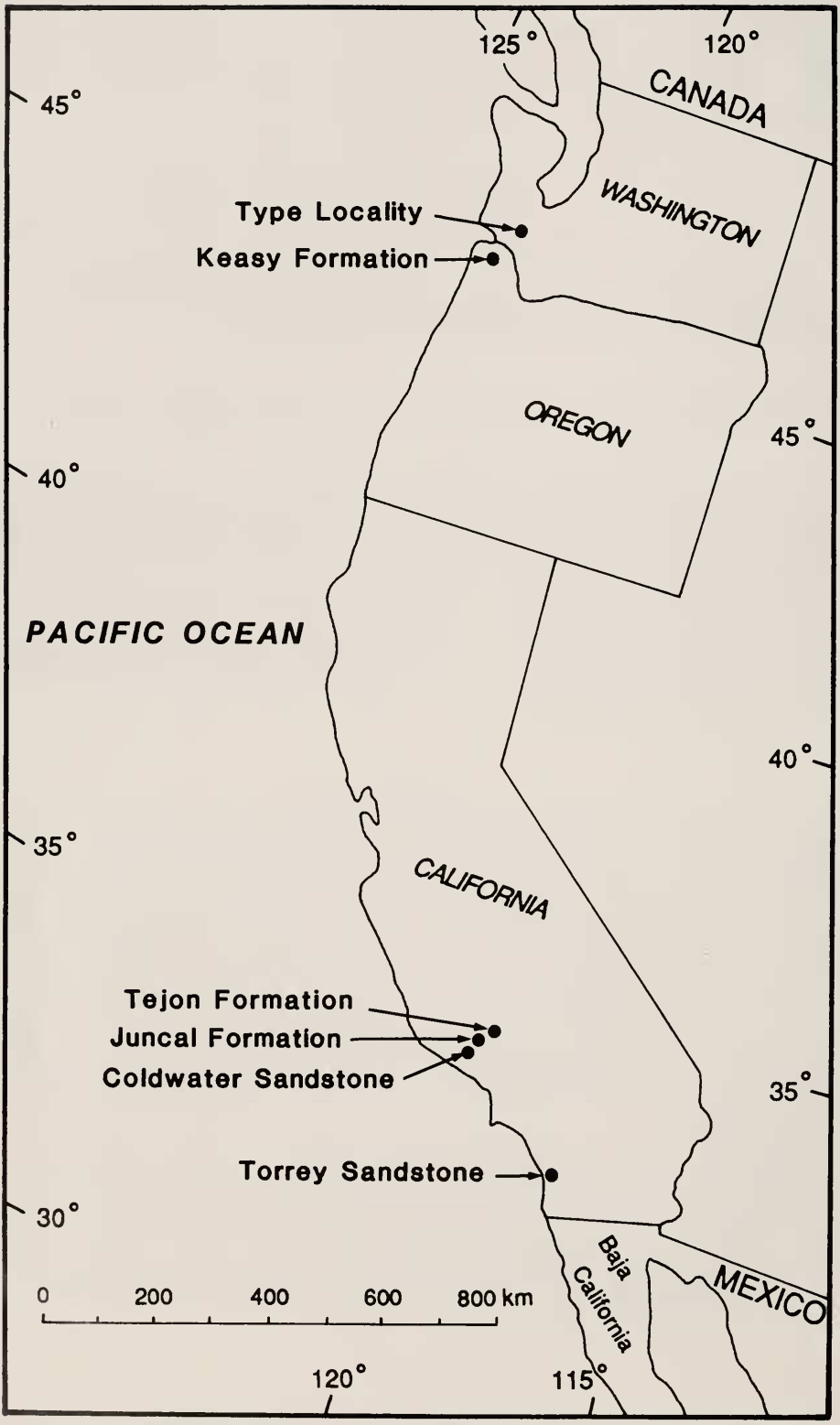

FIGURE 1. Stratigraphic occurrences of *Isognomon* (*Isognomon*) *clarki* (Effinger, 1938).

Observations on the height of the ligamental area and number of ligamental grooves of modern *Isognomon* were made on specimens in the malacological collections of the San Diego Society of Natural History.

The usage of molluscan provincial Eocene stages for California is based on Clark and Vokes (1936) with modifications by Givens (1974). The ages of these stages follow Saul (1983) and Squires (1984, 1987). The usage and ages of molluscan Eocene stages for northwestern Oregon and Washington follow Armentrout (1975, 1981).

Abbreviations used for catalog and/or locality numbers are CSUN, California State University, Northridge; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; SDSNH, San Diego Society of Natural History; UCR, University of California, Riverside; UCMP, University of California Museum of Paleontology, Berkeley.

Stratigraphic Occurrences

Type Locality.—Effinger (1938) named and reported *Isognomon* (*Isognomon*) *clarki* [= *Pedalion clarki*] from the Gries Ranch beds, just east of Vader, Lewis County, southwestern Washington. Only two valves were found, at locality UCMP 3607. Mainly on the basis of the abundance of sessile nearshore invertebrates, he interpreted the environment to have been nearshore or littoral. C. S. Hickman (*personal communication*, 1988), however, believes the shallow-water invertebrates were transported into a deep-water environment. Durham (1944:112, fig. 7) assigned the Gries Ranch beds to his *Molopophorus stephensoni* megafaunal Zone. Armentrout (1975) assigned the *M. stephensoni* Zone to the *Echinophoria dalli* Zone in the lower part of the Lincoln Creek Formation and in the middle of his Galvinian Molluscan Stage of late Eocene age.

California.—Givens (1974) reported the first occurrence of *Isognomon* from the Eocene of California. His specimens were from the upper half of the Juncal Formation, Pine Mountain area, Ventura County, southern California, at a single locality (UCR 4752) in a lens of calcareous sandy conglomerate. He identifed these specimens as *Isognomon* n. sp.? pending the discovery of more complete material. Givens' material consists of three large (up to 14 cm in height) articulated and two fragmentary specimens. From the presence of *Isognomon* and associated mollusks he interpreted this *Isognomon*-bearing bed as having formed in a shallow-water (inner sublittoral) environment at the seaward margin of a delta. The bed lies within the *Turritella uvasana applinae* fauna of the Juncal Formation, and this fauna is equivalent to the West Coast megainvertebrate provincial middle Eocene "Domengine Stage."

The new stratigraphic occurrence of *I.* (*I.*) *clarki* in the Torrey Sandstone is near the top of the formation, east of the city of Del Mar, in a new development called North City West, San Diego County, southern California. A 20-m-thick section of the Torrey was exposed in 1985 by bulldozing during construction. A 15-m-thick section of Ardath Shale was also exposed. The contact between the two units was sharp, and locally the claystone of the Ardath draped over cobbles at the top of the Torrey Sandstone. Overlying the Ardath was 10 m of the Scripps Formation. A housing tract now covers most of the entire section.

Specimens of *I.* (*I.*) *clarki* were found near the top of the 20-m-thick section of the Torrey Sandstone. The collecting site was a 30- to 60-cm-thick pebbly sandstone bed at locality SDSNH 3282. Thirty-three specimens were collected, of which 15 were right valves and 17 were left valves. Only a single articulated specimen was found. Most of the specimens are fragmentary, but preservation of the shell material is excellent. Only one complete left valve 12.5 cm in height (hypotype SDSHN 35235) (Figures 2.1, 2.2) was found. No complete right valves were found, but the best example is hypotype SDSNH 35236 (Figures 2.3, 2.4).

Mollusks in the Torrey Sandstone are rare. Previously, only two species were reported by Givens and Kennedy (1979:85). Associated shallow-water mollusks at locality 3282, however, are common. Other taxa include a solitary coral, a bryozoan, a brachiopod, barnacle fragments, a brachyuran, four shark species, a ray, a turtle, a glyptosaurine lizard, and a rodent (T. A. Deméré, *personal communication*, 1988).

A nearshore environment for locality 3282 is indicated by the mixing of marine and nonmarine fauna. According to Givens and Kennedy (1979), a middle Eocene age ("Domengine Stage") for the Torrey Sandstone is indicated by that formation's interdigitating with the lower part of the more readily dated middle Eocene Ardath Shale.

FIGURE 2. *Isognomon* (*Isognomon*) *clarki* (Effinger, 1938), middle Eocene ("Domengine Stage") upper Torrey Sandstone, locality SDSNH 3282. 1–2, SDSNH hypotype 35235, left valve, ×0.6, height 12.5 cm, width 10.8 cm. 1, exterior. 2, interior. 3–4, SDSNH hypotype 35236, partial right valve, ×0.7, height 9 cm, width 9.7 cm. 3, exterior. 4, interior.

The new stratigraphic occurrence of *I.* (*I.*) *clarki* in the Tejon Formation is in the basal part of the formation, Tehachapi Mountains, Kern County, south-central California. This part of the formation is rarely exposed because it is normally covered by extensive landslides and/or slope wash. A road cut made in 1971 along the east side of the Edmonston Pumping Plant, however, exposed a 122-m-thick section. The lowest 27 m consists of shoreline-associated deposits laid down as a transgressing sea advanced over an irregular surface of gneissic bedrock. Channel-lag storm accumulations of oyster hash and other mollusks indicate a rocky nearshore environment (Squires 1989).

At locality CSUN 1201, 13 m above the base of the section, numerous *Isognomon* valves (up to 9 cm in height) were found in closely packed layers. Twenty-four specimens were collected, three of which are articulated and range in height from 6 to 8 cm. They indicate that the distance of postmortem transport was short. The other specimens consist of six right valves and 12 left valves, all

poorly preserved and consisting of only partial shells (chalky) or internal molds. Above 27 m, mollusk-bearing channels are scarcer, and mollusks indicating subtidal environment increase (Squires 1989). Single fragmentary specimens of *I.* (*I.*) *clarki* were found at localities CSUN 1202 and 1203, 19 and 63 m, respectively, above the base.

Nilsen (1987:90–92, fig. 58) listed mollusk species from a few beds in the Edmonston Pumping Plant section and diagrammed the section. *Isognomon* was not listed; neither was it found by early workers (Gabb 1864; Dickerson 1915, 1916; Anderson and Hanna 1925) who described molluscan faunas from the Tejon Formation in the Tehachapi Mountains and the adjacent San Emigdio Mountains.

The lower 63 m of the Edmonston Pumping Plant section is of middle Eocene age ("Transition Stage"), as indicated by the overlapping of *Turritella uvasana uvasana* and *Ficopsis remondii crescentensis*. The remaining 59 m is of middle Eocene age ("Tejon Stage"), as indicated by the presence of *Turritella uvasana sargeanti* (Squires 1989).

The new stratigraphic occurrence of *I.* (*I.*) *clarki* in the Coldwater Sandstone, upper Sespe Creek, Ventura County, southern California, is at locality CSUN 252. The formation in this area has received very little geologic study. Four large (up to 12 cm in height) articulated specimens were found in well-sorted fine-grained sandstone. Associated mollusks include abundant very large (up to 18 cm in height) articulated oysters and a few articulated *Venericardia* sp. Sturdy-shelled oysters and *Venericardia* remaining *in situ* indicates nearshore shallow water. The well-sorted nature of the sandstone supports this interpretation and suggests a sand-bar environment.

Oregon.—The new stratigraphic occurrence of *I.* (*I.*) *clarki* in the Keasey Formation is in the upper part of the middle member of the formation at the Smithwick Haydite quarry, south of Vernonia, Columbia County, northwestern Oregon. An articulated partial specimen was found in siltstone at locality LACMIP 5806. C. S. Hickman (*personal communication*, 1988) collected two additional specimens from this quarry. Both are articulated and one is complete. Hickman (1976) interpreted the environment of the Keasey Formation to be bathyal. The articulated specimen of *Isognomon* is anomalous in this deep-water assemblage. *Isognomon* today may attach itself to roots of mangrove trees (Emerson and Jacobson 1976). Its occurrence in the Keasey may have resulted from individuals being attached to floating wood that eventually sank in deep water.

The Keasey Formation is of late Eocene age (Hickman 1976, 1980; Armentrout *et al.* 1983). The *I.* (*I.*) *clarki* specimen from locality LACMIP 5806, therefore, is of the same geologic age as those from the type locality found by Effinger (1938).

Systematic Paleontology

Class Bivalvia Linné, 1758
Subclass Pteriomorphia Beurlen, 1944
Order Pterioida Newell, 1965
Suborder Pteriina Newell, 1965
Superfamily Pteriacea Gray, 1847
Family Isognomonidae Woodring, 1925
Genus *Isognomon* Solander in Lightfoot, 1786

Type Species.—By monotypy, *Ostrea perna* Linné, 1767, Recent, Indo-Pacific.

Subgenus *Isognomon* s.s.
Isognomon (*Isognomon*) *clarki* Effinger, 1938
Figure 2.1–2.4

Pedalion clarki Effinger, 1938:367–368, pl. 45, figs. 9–10. Weaver, 1943:77, pl. 13, fig. 9.
Isognomon n. sp.? Givens, 1974:43–44, pl. 2, fig. 6.
Isognomon (*Isognomon*) n. sp.? Givens. Moore, 1983:85, pl. 26, fig. 1.

The Torrey Sandstone specimens are better preserved than the primary type specimens, warranting the following supplementary description: equivalved, inequilateral, subquadrate, moderately inflated, and large (up to 14 cm in height); prosogyrate beaks somewhat extended anteriorly; anterior margin nearly straight, becoming concave near beak and reflected and forming a ridge in byssal gape area below beak, reflection more pronounced on left valve; angle between hinge line and anterior

margin about 65°; posterior and ventral margins evenly rounded; hinge line straight with up to 21 ligamental grooves that are about half as wide as the interspaces, posteriorly the interspaces become wider; ligamental area flat and broad to very broad, depending on the particular specimen; very narrow byssal gape below beaks; pallial line near anterior margin marked by small nodes and pits; shell surface with closely spaced growth lines; holotype height 12.5 cm, length 11 cm, (h/l = 1.14), width of both valves together 3 cm.

Discussion.—The use of the subgenus *Isognomon* in this present report follows Cox (1969).

All the West Coast Eocene isognomonid specimens are judged to be *I.* (*I.*) *clarki* because they are morphologically inseparable. The only differences are minor and fall within limits of normal variation seen in comparably sized modern species of *Isognomon*. The two adult specimens of *I.* (*I.*) *clarki* shown in Figure 2 differ in the height of the ligamental area and number of ligamental grooves. This kind of variation is also present in adult specimens of *I. recognitus* from Kino Bay, Sonora, Mexico, with a few specimens having ligamental area heights 25 percent greater than that of the average specimen. Similary, the height of the ligamental area in adult specimens of *I. isognomum* from Manila, Philippine Islands, varies from specimen to specimen, with a few specimens having heights 50 percent greater than the average. In addition, there are 19 ligamental grooves in young adults versus 23 ligamental grooves in mature adult specimens of this species.

The specimen shown in Figures 2.1 and 2.2 is the widest known specimen of *I.* (*I.*) *clarki* because it is the most complete specimen of this species.

Isognomon (*I.*) *clarki* is most similar to *Isognomon* (*I.*) *panzana* (Loel and Corey, 1932:187, pl. 9, figs. 1a–b, 2–6) from the upper Oligocene and Miocene Vaqueros Formation, California. Moore (1983:84, pl. 25, figs. 3 and 6) also figured this species. *Isognomon* (*I.*) *clarki* differs from *I.* (*I.*) *panzana* in the following features: much wider, h/l = 1.1 rather than 1.8, angle between hinge line and anterior margin about 65° rather than about 75°, 12 rather than 9 ligamental grooves in specimens about 9 cm high, irregular divaricate-radial plications on the exterior absent, and posterior ventral margin not crenulate.

A specimen from the lower Eocene Meganos Formation of north-central California, referred to as *Pedalion* sp. by Clark and Woodford (1927:88, pl. 14, fig. 8), may be an *Isognomon* and may be conspecific with *I.* (*I.*) *clarki*. Moore (1983:84–85, pl. 26, fig. 3) identified this specimen as *Isognomon* sp. My examination of this tiny (height 12 mm) fragmentary specimen revealed that it does have a straight hinge line, but the view is of the exterior and no ligamental grooves can be seen. More material of this species is needed for an identification to genus.

Material.—Sixty-six specimens.

Occurrence.—"Domengine Stage" through Galvanian Stage, equivalent to the upper lower through upper Eocene (upper Ypresian through Priabonian stages of Europe).

"Domengine Stage": Upper Torrey Sandstone, northern San Diego County, southern California (locality SDNHM 3282); upper Juncal Formation, *Turritella uvasana applinae* fauna, Pine Mountain area, Ventura County, southern California (locality UCR 4752).

"Transition Stage": Lower Tejon Formation, Kern County, south-central California (localities CSUN 1201, 1202, 1203).

"Tejon Stage": Coldwater Sandstone, upper Sespe Creek, southern California (locality CSUN 252).

Galvanian Stage (equivalent to the "Tejon Stage"): Upper part of the middle member of the Keasey Formation, Smithwick Haydite quarry, Columbia County, northwestern Oregon, (locality LACMIP 5806); lower Lincoln Creek Formation, near Vader, Lewis County, southwestern Washington (locality UCMP 3607).

Repositories.—Holotype, UCMP 33513. Paratype, UCMP 33514. Hypotypes, UCR 4752/61; SDSNH 35235 and 35236.

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A. E. Fritsche, California State University, Northridge, found the Coldwater Sandstone specimens. C. S. Hickman, University of California, Berkeley, showed me additional specimens of *Isognomon* from the Keasey Formation.

C. L. Powell, II, U.S. Geological Survey, Menlo Park, arranged loans of mollusks associated with the *Isognomon* from the basal Tejon Formation. R. C. Brusca, San Diego Natural History Museum, allowed access to the malacological collections.

Al Grmela, Department of Water Resources, Bakersfield, granted permission to enter and collect specimens at the Edmonston Pumping Plant. Mildred Wiebe, Tejon Ranch, granted permission for paleontologic investigations on the Tejon Ranch area west of the Edmonston Pumping Plant.

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Localities

All the quadrangle maps listed below are 7.5-minute, unless otherwise specified.

CSUN 252. Just north of upper Sespe Creek, NW 1/4, SW 1/4, SW 1/4 of section 35, T 6 N, R 22 W, Lion Canyon quadrangle, California (1943).

CSUN 1201. Roadcut exposure about 20 m east of the eastern side of Edmonston Pumping Plant, 13 m above base of Tejon Formation, Pastoria Creek quadrangle, California (photorevised 1974). Equivalent to U.S. Geological Survey, Menlo Park, Cenozoic collection locality M4631, given in Nilsen (1987:90).

CSUN 1202. Roadcut exposure about 20 m east of the eastern side of Edmonston Pumping Plant, 19 m above base of Tejon Formation, Pastoria Creek quadrangle, California (photorevised 1974).

CSUN 1203. Roadcut exposure about 60 m N5 E of the northeast corner of Edmonston Pumping Plant, 63 m above base of Tejon Formation, Pastoria Creek quadrangle, California (photorevised 1974). Equivalent to U.S. Geological Survey, Menlo Park, Cenozoic collection locality M4633, given in Nilsen (1987:91).

LACMIP 5806. Smithwick Haydite Quarry, 0.4 km north of the high trestle across Oregon Highway 47, 13.6 km south of Vernonia, Washington County, Oregon.

SDNHM 3282. Hillside exposure (now mostly covered), 330 m north and 330 m east of southwest corner of section 8, T 14 S, R 3 W, Del Mar quadrangle, California (1967).

UCMP 3607. In south bank of Cowlitz River at the old Gries Ranch in the NW 1/4 of section 25, T 11 N, R 2 W, Castle Rock 15-minute quadrangle, Washington (1953).

UCR 4752. On the crest of a southwest-trending ridge northeast of the main fork of Piru Creek, 525 m south and 735 m east of the northwest corner of section 29, T 7 N, R 21 W, San Guillermo quadrangle, California (1943).

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